

# CONSTRUCTION STATUS OF THE KEKB 8-GEV INJECTOR LINAC

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## Abstract

The KEKB (B-Factory at KEK) 8-GeV injector linac is under construction by upgrading the existing 2.5-GeV injector as well as extending the linac towards the upstream site. This upgrade has been almost completed and the two linacs are presently being combined. This paper describes the construction status, with emphasis on the newly developed beam monitors being used for various stages of beam commissioning.

## 1 INTRODUCTION

KEKB includes an 8-GeV electron ( $e^-$ ) ring and a 3.5-GeV positron ( $e^+$ ) ring, which has been under construction since the TRISTAN accelerator was removed. KEKB aims at a luminosity of  $1 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$  with collisions between 1.1-A electrons and 2.6-A positrons. One of the requirements of the injector linac is to deliver full-energy beams for both rings. The other is to increase the positron beam intensity to ten-times as much as what the old 2.5-GeV linac [1] produced; when the linac injects with a charge of 0.64 nC/bunch at 50 Hz and without any beam loss, it takes 13.5 minutes to accumulate from 0 to a maximum charge of 26  $\mu\text{C}$ , since the KEKB ring has a circumference of about 3 km. The main parameters of the KEKB injector linac are given in Table 1.

In order to achieve these requirements, the linac has been reconstructed and expanded, as shown in Fig.1. For the energy upgrade, the number of accelerator units was increased from 40 to 57 with an acceleration gain of 160 MeV each; for increasing the rf peak power, the klystron modulator power was increased by twice, the 30-MW klystrons replaced by 50-MW klystrons, and rf pulse compressors used.

The old positron generator was moved to a higher energy point of about 4 GeV from 0.2 GeV in order to increase the positron intensity.

The basic design details have been reported elsewhere [2].

## 2 CONSTRUCTION STATUS

The KEKB project was approved in FY 1994 as a five-year program; the fourth year has already passed.

### 2.1 Upgrade of the existing linac

Since the project began, upgrading of the existing 2.5-GeV linac has gradually been performed.

By the end of FY1997, of the existing 40 accelerator units, 38 had been upgraded; 37 units were upgraded with higher power klystrons and rf pulse compressors. In a unit just after the positron generator, the rf compressor is not used for avoiding any disadvantage of rf breakdown.

Two accelerator units have not yet been installed: One unit (#C-7, see Fig.1) is being used as a temporary pre-injector for the PF, because the original pre-injector was moved to the most upper-stream end of the KEKB injector. The other is unit #5-8, which has been appropriated for an energy compression system (ECS).

TABLE 1  
Parameters of the KEKB  $e^-/e^+$  injector linac.

[Beam]		
Injection energy	( $e^-$ )	8.0 GeV
	( $e^+$ )	3.5 GeV
	( $e^-$ for $e^+$ production)	3.7 GeV
Pulse length		single bunch
Bunch (half) width ( $\sigma_z$ )		5 ps
Particle number (Charge) / pulse	( $e^-$ )	$8 \times 10^9$ (1.28 nC)
	( $e^+$ )	$4 \times 10^9$ (0.64 nC)
	( $e^-$ for $e^+$ production)	$6 \times 10^{10}$ (10.0 nC)
Pulse repetition		50 pps
Emittance ( $2\sigma$ )	( $e^-$ )	$6.4 \times 10^{-8}$ m.rada
	( $e^+$ )	$8.8 \times 10^{-7}$ m.rada
Energy (half) width ( $\sigma_E/E$ )	( $e^-$ , $e^+$ )	0.125%
[RF]		
frequency		2856 MHz
average klystron output power		41 MW
pulse width		4.0 $\mu\text{s}$
Energy multiplication by rf compressor		1.8
[Accelerator unit]		
including four 2-m traveling-wave accelerator sections		
Total number		57
Number before $e^+$ radiator		26
Energy gain per accelerator unit		160 MeV/unit
(except for the pre-injector and after $e^+$ radiator)		

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The temporary pre-injector has a gun, a prebuncher, and a main buncher. In order to combine the extended linac with the existing linac, and continue PF injection, the gun has been installed off the beam line with a 90-degree bending magnet. The electron beams from the temporary pre-injector were accelerated through the entire linac. Beams of about 300 pC/pulse could be transmitted at a gun beam of 500-pC.

All of the beam-transport magnets of the existing linac were replaced or improved so as to accommodate higher energy beams, adding beam-position monitors at every location of the quadrupole magnets.

Rf conditioning was continued during May and June, 1997, in order to achieve an average rf power of 41 MW. Some of them, which had been upgraded before the summer of 1996, were conditioned up to this target within 3 weeks; others took 5 weeks, and one did not achieve this goal. Since electric discharging was frequently observed for a faster rf phase-switching time concerning SLED, in such cases the switching time was loosened up to about 0.2  $\mu$ s during conditioning.

Because an energy-analyzing station (EAS) at the end of the linac, which can measure energy up to 8 GeV, had not yet been prepared, an EAS at the end of Sector 2 was used in order to prove the acceleration gain. The beam energy was measured to be 2.16 GeV. Since a pre-injector and 13 accelerator units were used, the average accelerator gain per unit was more than 160 MeV, which is the target of the KEKB linac.

### 2.2 Extended linac

The expansion buildings were completed by January, 1996. The extended linac has a pre-injector and 17 accelerator units. These are divided into Sector A to C, as shown in Fig.1.

In the pre-injector (unit #A-1), before a pre-buncher and a buncher of fundamental frequency, 114.24-MHz and 571.2-MHz sub-harmonic bunchers (SHB) were added in order to compress 2-ns gun pulses to single-bunch beams. The power supplies for the SHB are 5 kW and 10 kW, respectively.

The extended was been constructed and tested separately from the existing linac during FY1997.

All of the accelerator units were finished by October, 1997. RF conditioning was started on October 7th, 1997. Using automatic conditioning software, it was successfully completed from upper stream. By December 24th, the upstream 1.5-GeV part before a 180-degree linac arc was commissioned.

The 180-degree linac arc, an achromatic and isochronous beam-transport system, was completed at the end of February, 1998. For dispersion and isochronicity corrections, bpm's and a streak camera were effectively used.

### 3 RESEARCH AND DEVELOPMENTS

There were various important contributions for constructing the KEKB injector linac [3]-[12]. For example, in order to replace the old klystrons while continuing operation for the PF ring, a dimension-compatible, compact high-power klystron was developed; for establishing a synchronizing system between the linac and ring accelerating frequency, a low phase-noise master oscillator of 571.2 MHz, multipliers, and dividers were newly fabricated; also new accelerator sections were fabricated by electroplating technology. These were reported at past international and domestic accelerator conferences.

In this paper, progress concerning beam-instrumentation system is described. We have used it in commissioning the extended part of the KEKB injector, as follows:

(1) Beam screens for:

- rough orbit adjustment,
- emittance measurement and matching with random-shutter cameras and an image-analyzing device,
- spectrum measurement,

(2) Beam position monitors for:

- automatic search for quadrupole center,
- betatron oscillation measurement,
- correlation plot of emittance growth vs. beam orbit,
- dispersion (Rn6, Rn66) measurements and correction in/after the linac arc,

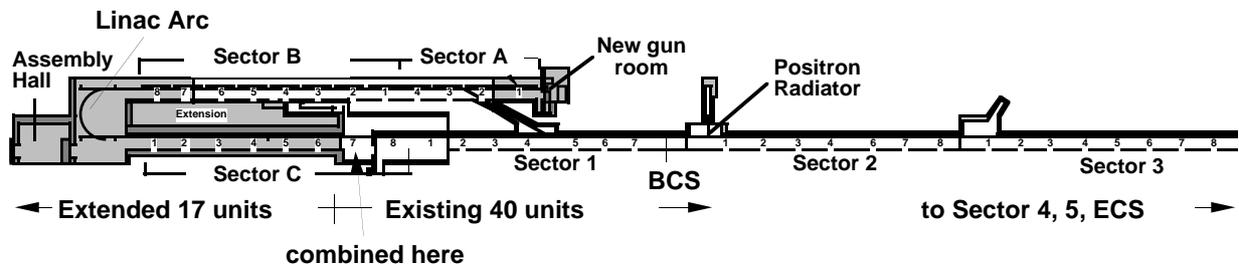


Fig.1 Layout of the 8-GeV  $e^-$  / 3.5 GeV  $e^+$  KEKB injector linac. Forty accelerator units of the old 2.5-GeV linac were energy-upgraded from about 67.5 to 160 MeV/unit in average; and, new 17 units were added at the upstream site. The old and new linacs were combined during March 23 to 30, 1998.

- energy-stability measurement in the arc,
  - fine correction of orbit distortion,
- (3) Streak Camera System for:
- bunch tuning and monitor in the pre-injector.
  - isochronicity (R56,R566) measurements and correction after the arc.

### 3.1 Streak-Camera Systems

A streak-camera system has also been used in the old linac since the 1980's to observe the bunch structure of the electron /positron beam. At an early year, air-Cherenkov light emitted by a beam was used as a light source into a streak camera. The system consisted of separate devices, such as an optical system, a trigger and its delay system as well as a streak camera proper. Since the trigger should be a low-jitter system, synchronization by accelerating rf (6th sub-harmonic, 476 MHz) is also required. Consequently, those systems were not so easy to handle. It sometimes took half a day to obtain the necessary signal. Therefore, it has for a long time been used only for experiments.

We have been improving such a system so as to be used for daily beam tuning in the linac, like when using an oscilloscope [12]. The developed streak-camera system has such characteristics as:

- an accuracy of 2 ps at a time-range of 0.3 ns,
- an overall trigger jitter of less than 2 ps after synchronization with 571.2-MHz accelerating sub-harmonics,
- an automatic peak search function between a time-range of 5 ns (widest) and 0.3 ns.(narrowest),
- a data-display repetition time of less than 1 s,
- integration of peaks arranging each center of gravitation,
- remote control of the optical lens system.

Thus, one of these are being used after the pre-injector in order to tune the bunch structure. Empirically, a charge of more than 1 nC/pulse gives sufficient light for seeing a single-shot signal without focusing the electron beam on the metal plate. The other was used after the linac arc in order to check the isochronicity of chromatic beams after passing through the arc.

### 3.2 Beam Position Monitor

Stripline-type beam position monitors were installed in front of each quadrupole [11]. For solving man-power problem to develop a data acquisition system, 17 digital sampling oscilloscopes, which are of 5 GHz, 2 ch, and commercially available, were distributed every half of the linac sector (typically  $76.8/2=38.4$  m). The signals are combined by combiners so that each peak is not overlapped, and introduced to oscilloscopes controlled by a VME computer. The signal peaks are measured using the oscilloscope functions and analyzed by VME. The position signals for one beam pulse are measured by a beam-trigger signal distributed to the monitor station.

The position information from all bpms is renewed every 1.4 second at present.

## 6 SUMMARY

(1) A linac upgrade was almost completed, and average accelerator gains of more than 160 MeV per unit (20 MeV/m) were obtained by a beam test.

(2) High-current acceleration and positron production are under investigation. Streak cameras and BPMs are effectively working for linac commissioning; a 10-nC single bunch could be accelerated to the end of Sector B; the linac arc has been successfully tuned. The electron-to-positron conversion rate was measured.

(3) The extended and existing linac are to be combined as the KEKB injector and fully commissioned on May and June, 1998.

## REFERENCES

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